

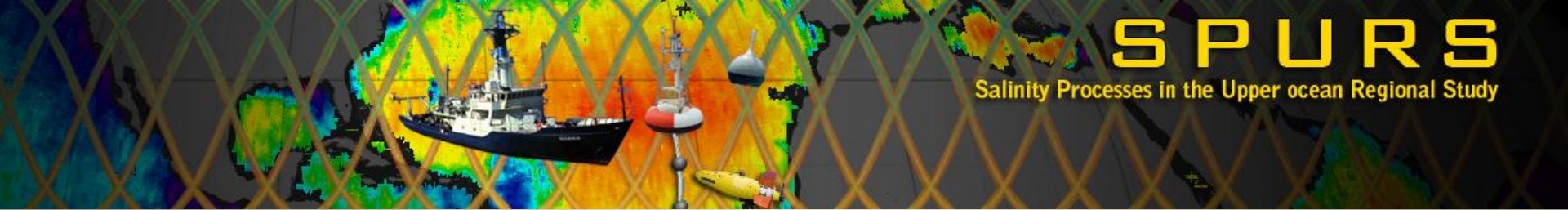


Mean Salt Balance of the North Atlantic Salinity Maximum

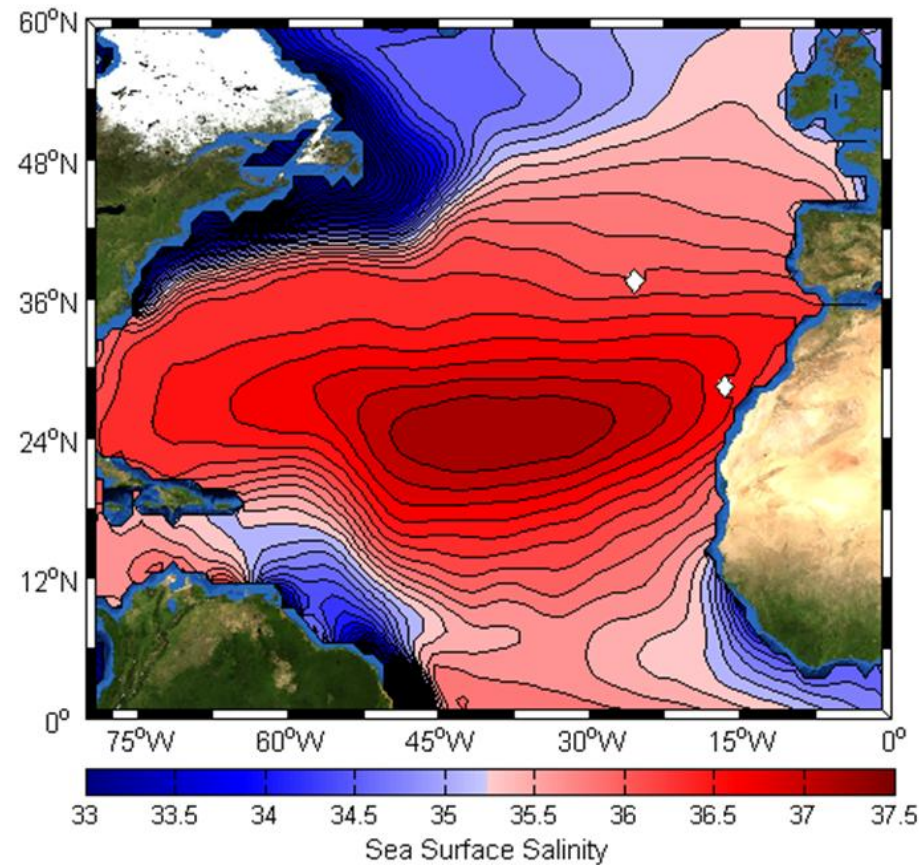
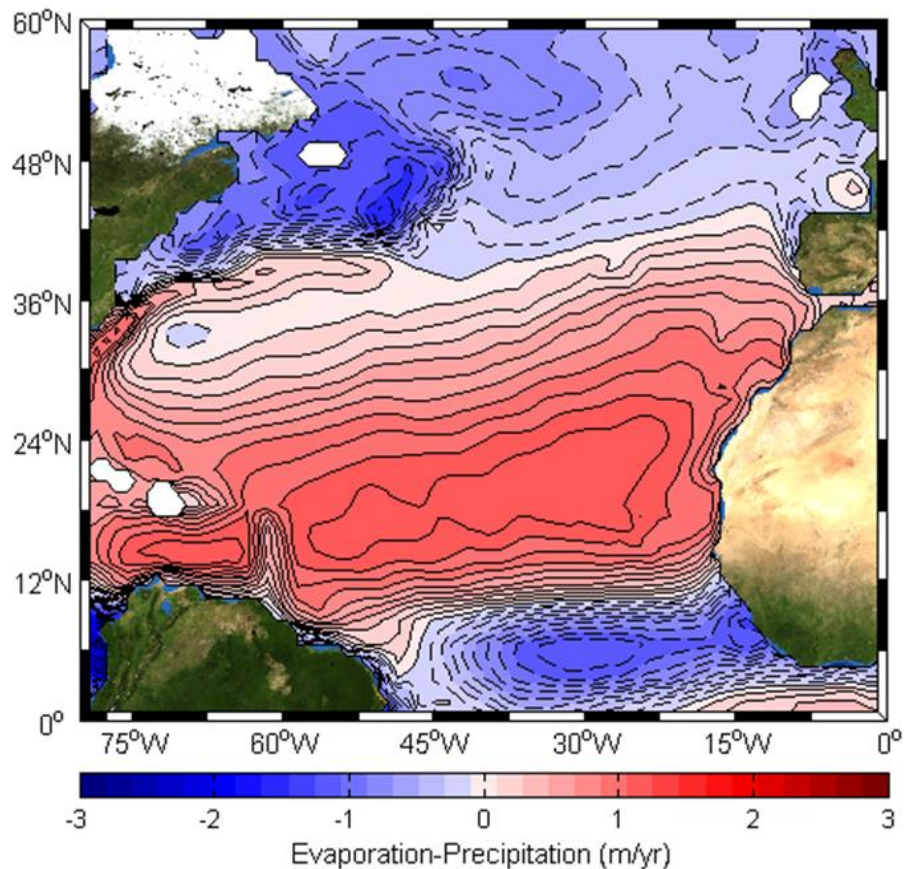
R. Schmitt, A. Blair,
L. St Laurent and J. Schanze

Woods Hole Oceanographic Institution





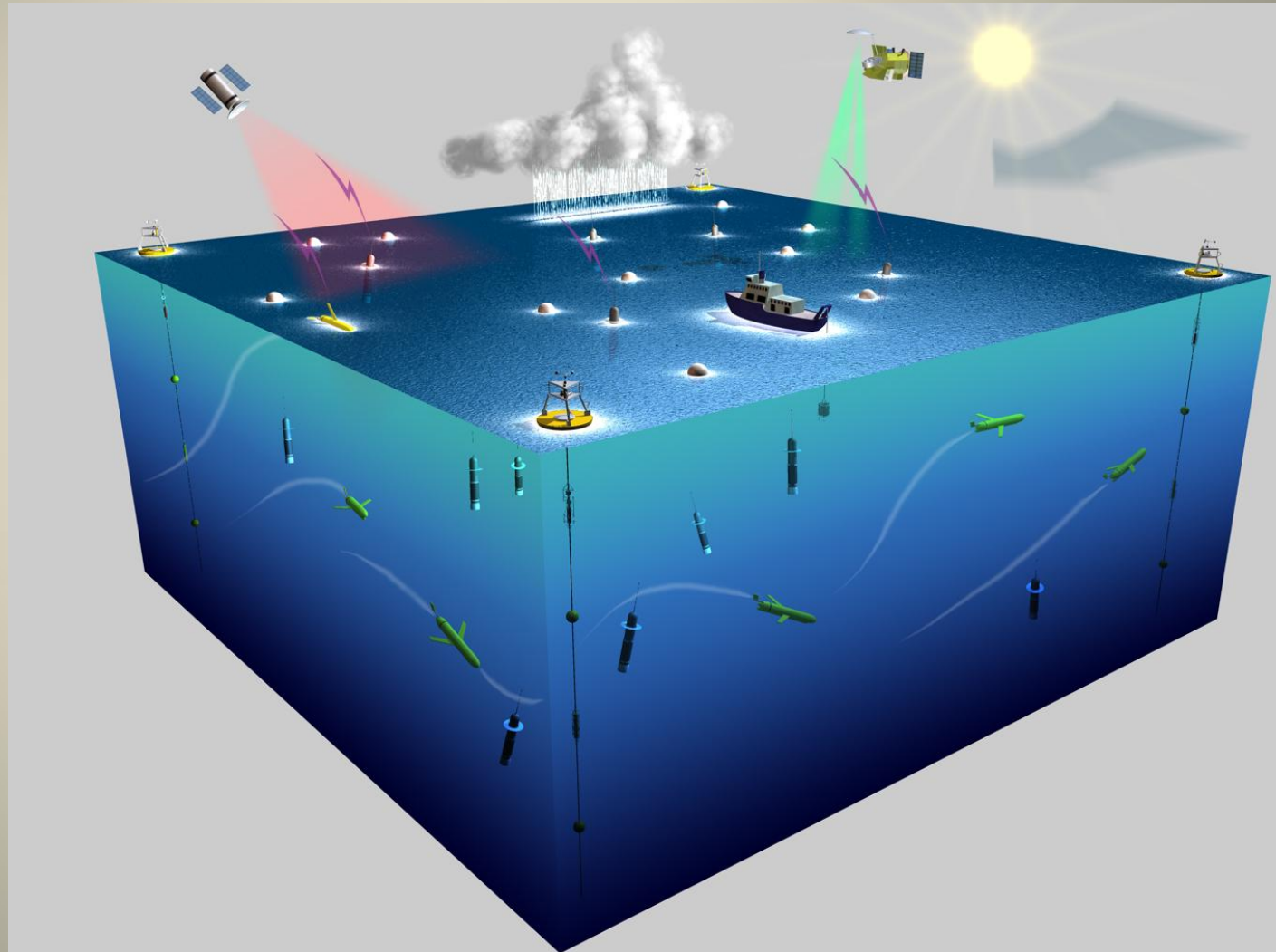
N. Atlantic evaporation-precipitation and salinity are highly correlated.



Note: the E-P zero line is close to vegetation/dry land boundary in Africa

Challenge: Integrating a diverse set of measurements

- Floats
- Gliders
- Drifters
- Moorings
- Ships
- AUVs
- Satellites
- CTD & Micro-structure profiling



SPURS Science Question:

How is the Salinity Maximum Maintained?

One Approach: **An “isohaline” control volume**

The idea goes back to Niiler and Stevenson (1982), “The heat budget of tropical ocean warm-water pools”, *J. Mar. Res.*, 40, 465–480.

Define a control volume by an isohaline, then the mean advective terms across this surface all have the same salinity and the balanced dynamical flows can be dropped from the equations (Ekman and Sverdrup circulations). Only the net water loss due to Evaporation minus Precipitation (E-P) counts in the mean advective salt balance. This must be compensated for by vertical and lateral mixing processes.

$$\nabla \cdot \mathbf{V} = 0, \quad (2)$$

Niiler and Stevenson, 1982

(J. Marine Research 40 (Supp.) 465-480)

$$-c\rho\overline{W'T'}|_{z=0} + q(0) = Q_o \quad . \quad (3)$$

Integrate equations (1) and (2) over an enclosed volume of the ocean which is bounded above by the sea surface A_s , continental land masses A_o and at depth, by a smooth three-dimensional surface A_T (Fig. 1). The result of this integration is, using Gauss' theorem and Eq. (3),

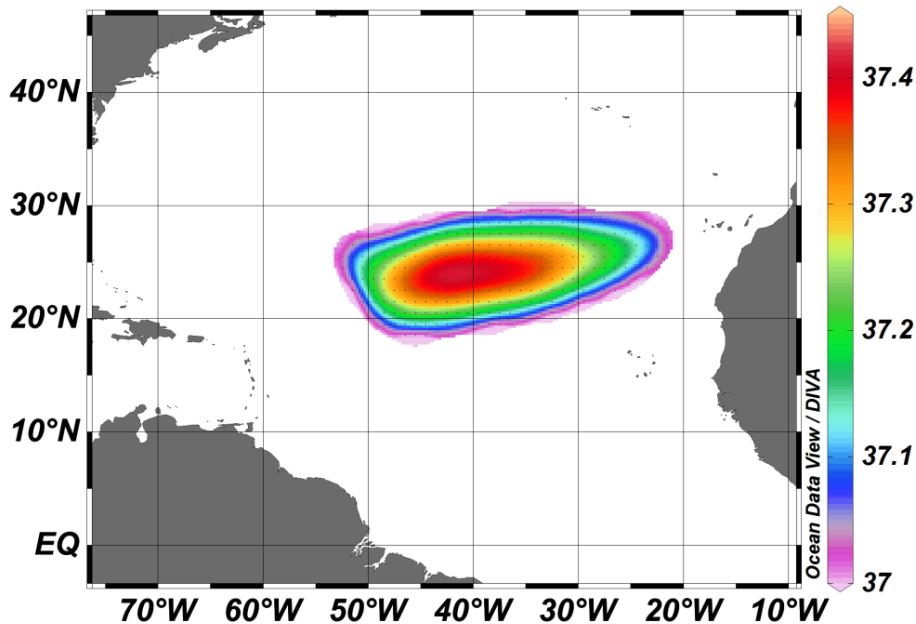
$$c\rho \left\{ \int \int_{A_T} V_n T ds + \int \int_{A_r} \overline{V'_n T'} ds \right\} = \int \int_{A_s} Q_o dA \quad , \quad (4)$$

$$\int \int_{A_T} V_n ds = 0 \quad . \quad (5)$$

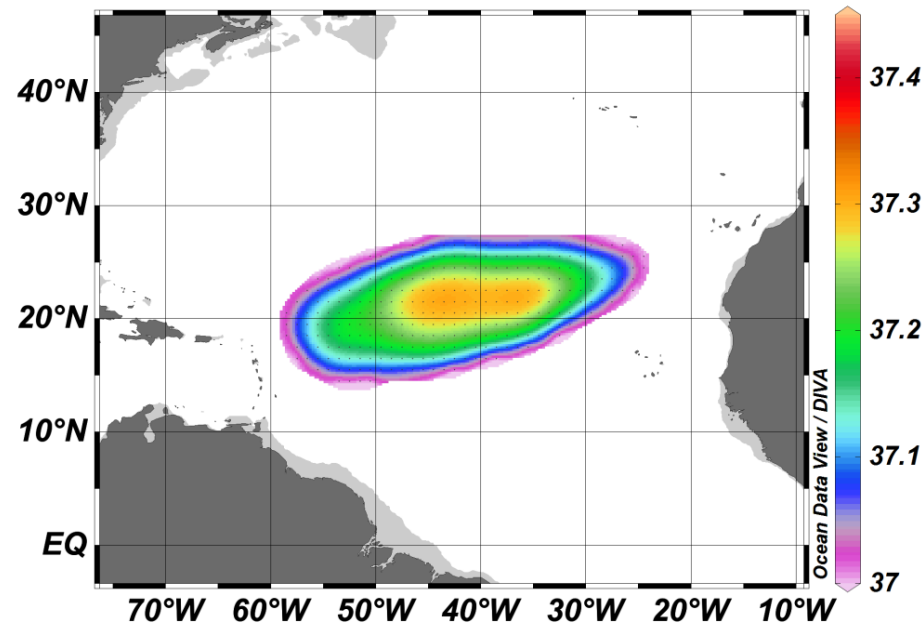
Can we define an isohaline control surface?

Horizontal Structure: Surface and 100 meters depth limit $S = 37.0$

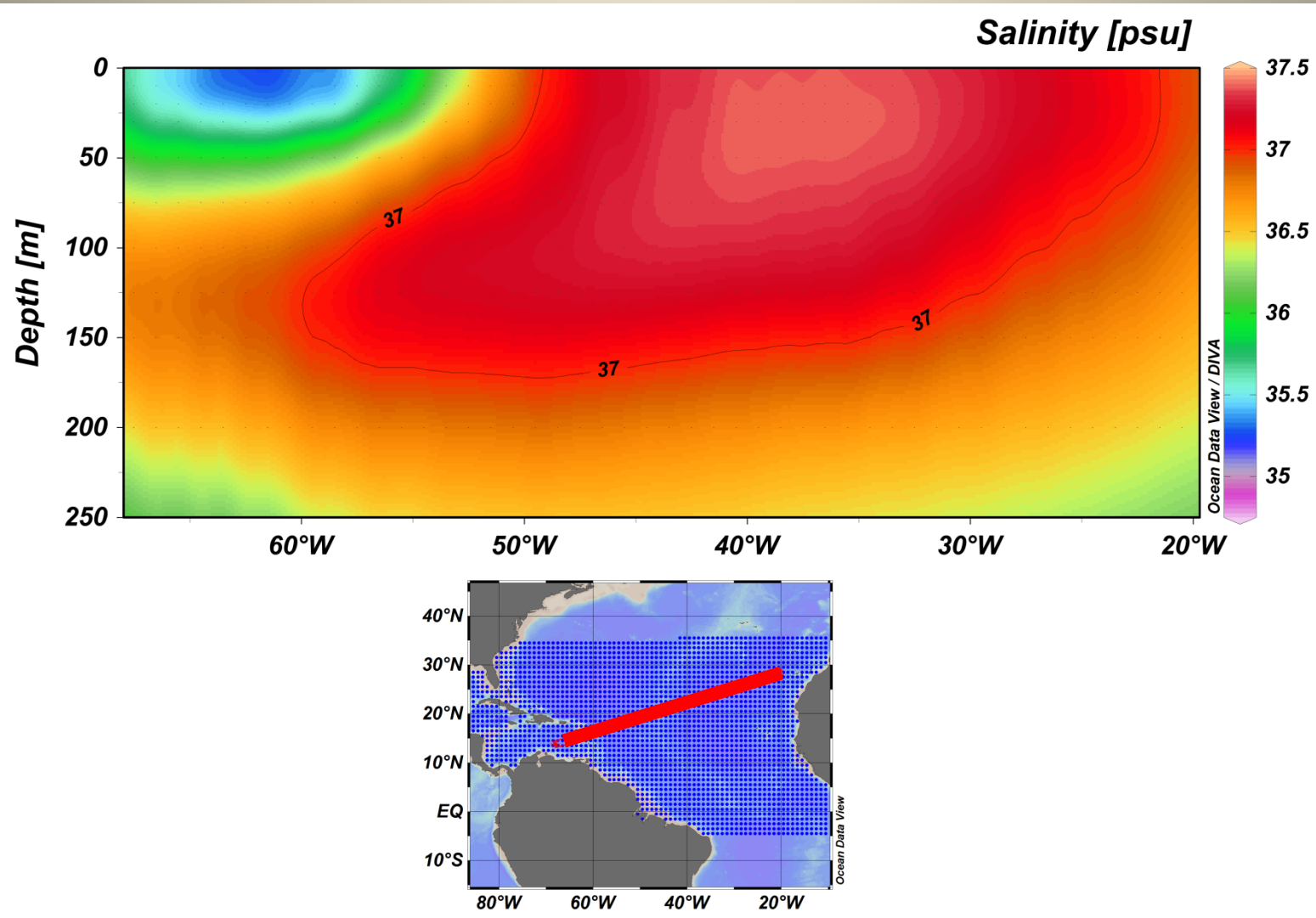
Salinity [psu] @ Depth [m]=0



Salinity [psu] @ Depth [m]=100

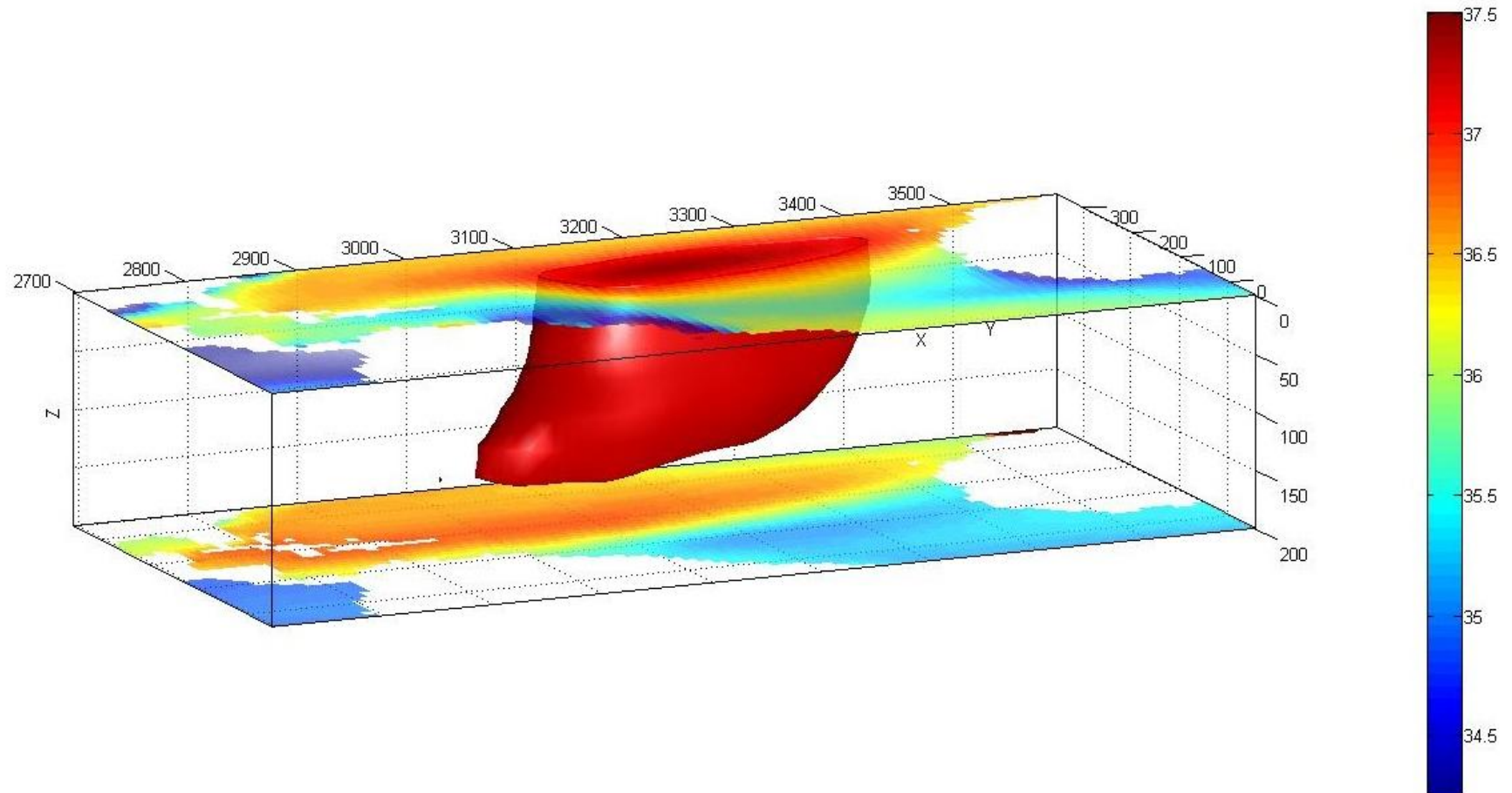


Vertical Structure of “Subtropical Underwater”

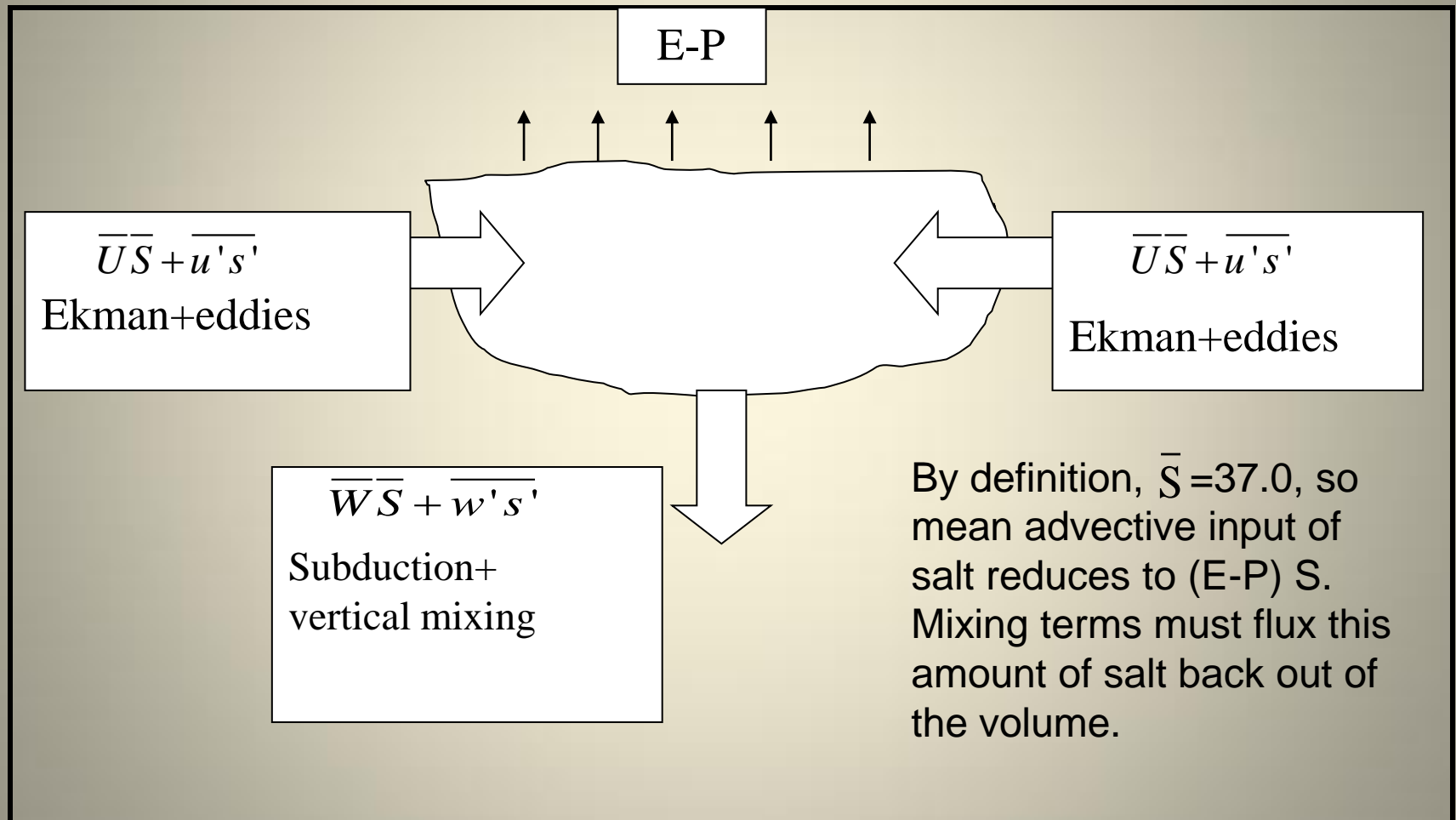


3-D Shape of the 37.0 Isohaline

Salinity Maximum Characteristics



Salt Fluxes

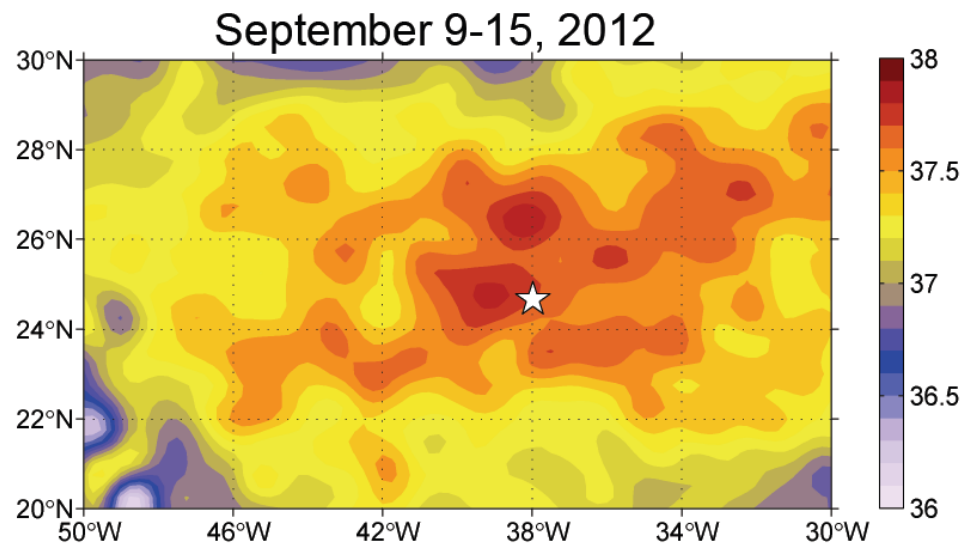
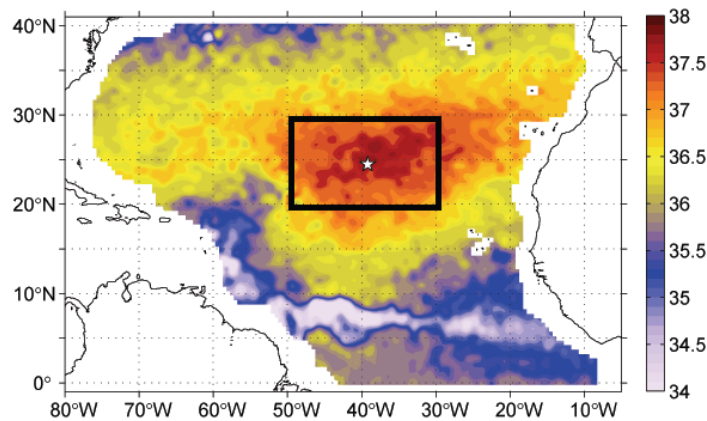


Motivation

Eddy Activity clearly seen in SSS field

International Pacific Research Center, SOEST, University of Hawaii

Aquarius OI SSS for SPURS



SPURS Meeting, Miami FL, 16-18 January 2013

Data sources

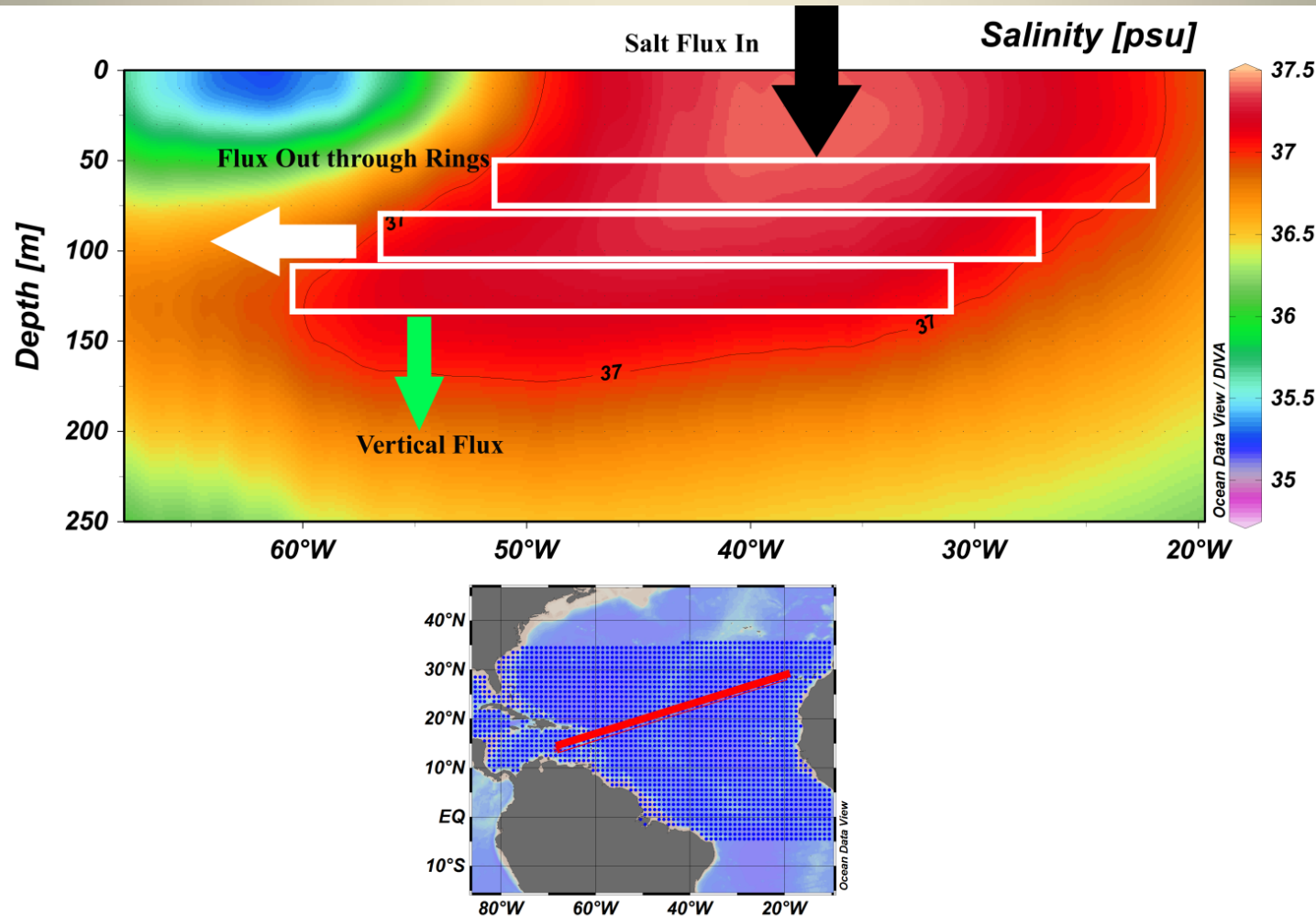
- Use World Ocean Atlas 2009
- Define volume by $S > 37.0$
- Surface Area = $2.9 \times 10^6 \text{ km}^2$
- Net water loss from E-P= 0.11 Sv

(Schanze, Schmitt and Yu, 2010)

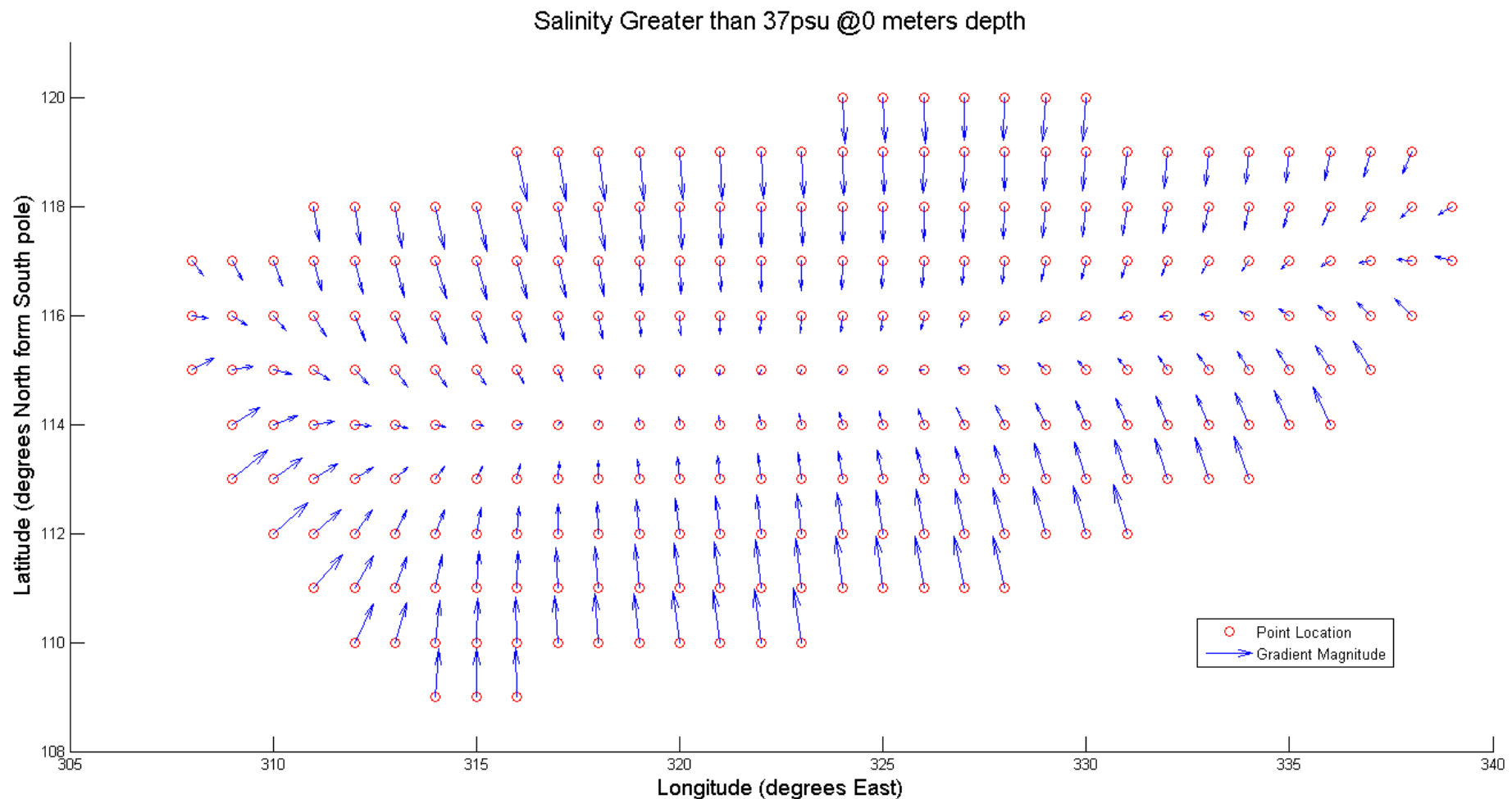
- Net surface salt flux = 3.9 psu-Sv

Diffusivity Calculations

3.9 PSU Sv



Calculation of Ring Areas and Gradients



Diffusivity Calculations

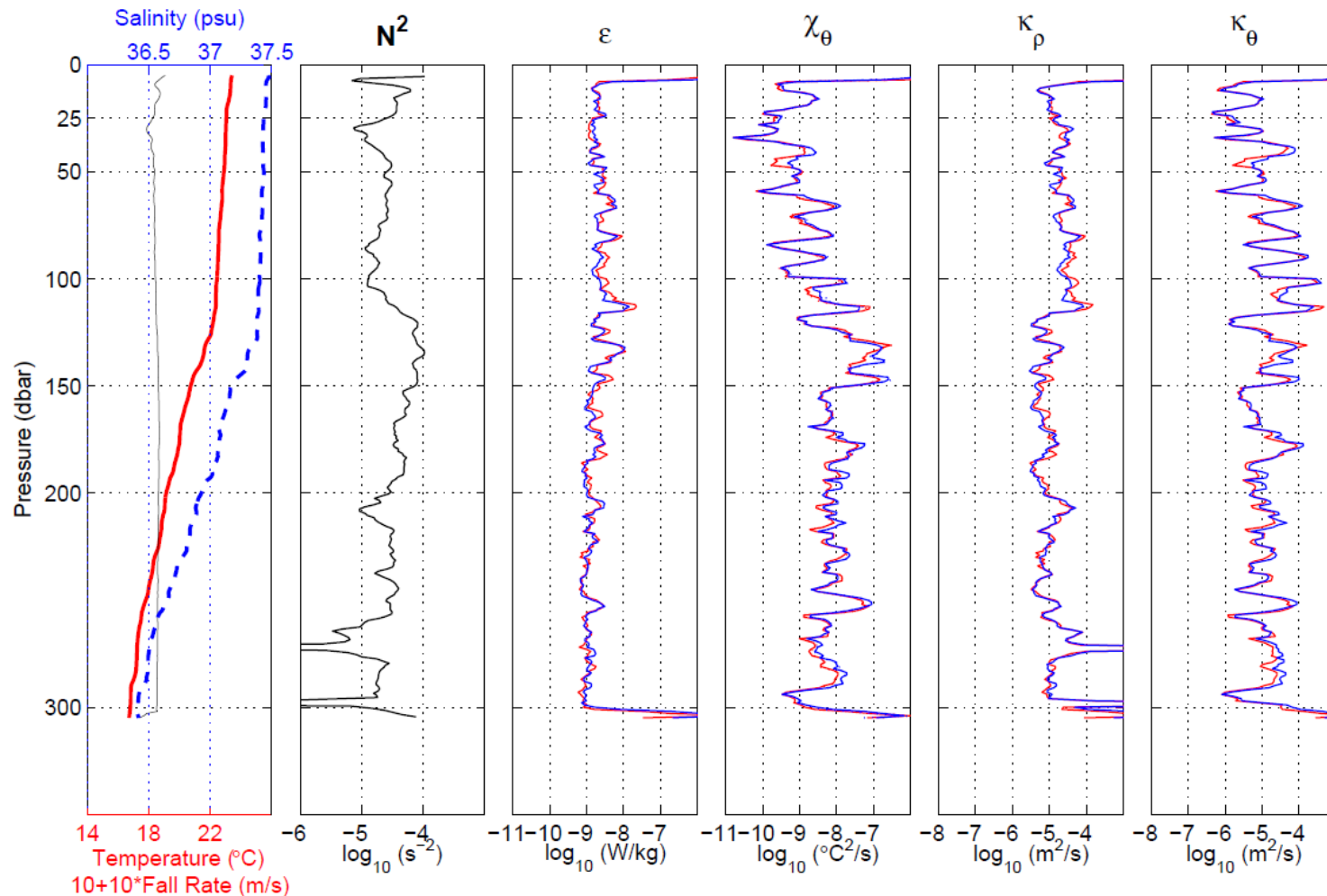
- Salt Flux: $F_S = (E - P) * S$
- Balance:

$$\int F_S dA_S = \int K_V S_z dA_B + \int K_H \nabla_2 S dA_W$$

Estimate K_V from microstructure measurements from VMP and T-Gliders

Microstructure from VMP

MMM SPURS Microstructure
VMP Dive No. 071 --- Mar. 31, 2013 15:03Z



First results:

- Average Turbulent diffusivity from ~1000 T-Glider dives at the 37.0 isohaline yields:
 $K_\rho = 6.8 \times 10^{-5} \text{ m}^2/\text{s} \rightarrow \text{salt flux} = 1.05 \text{ PSU-Sv}$
- Vertical mixing accounts for $\sim 1/4$ of the salt flux put in at the surface.
- But just a snap shot.....
- St Laurent and Schmitt (1999) had a lower diffusivity deeper and further northeast
- Salt fingers are part of the mixing

Lateral Mixing

$$K_Y = \frac{\text{Surface flux} - \text{Vertical Mixing}}{\int \nabla S dA}$$

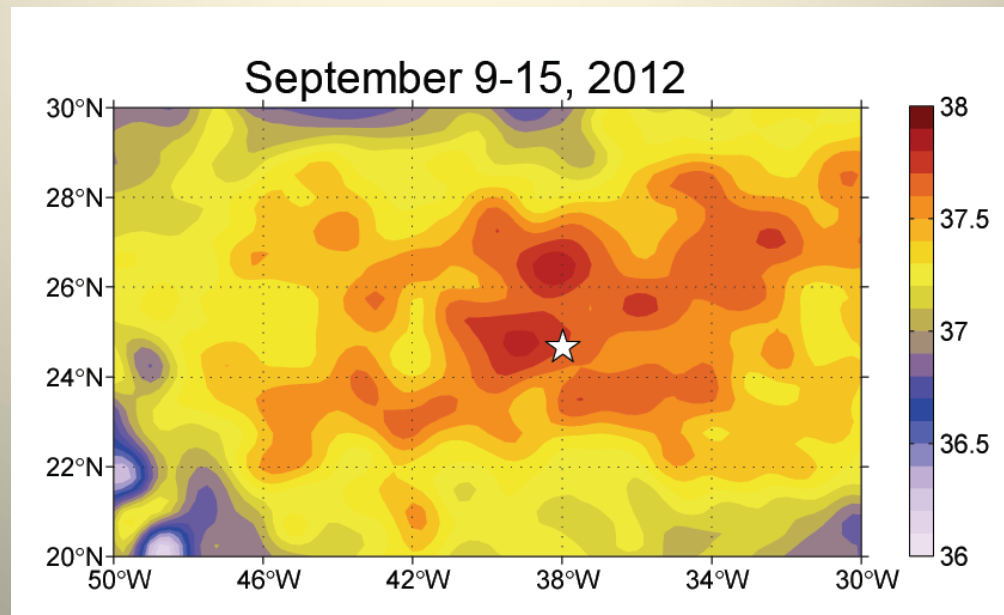
$$K_Y \approx \frac{0.75 \times 3.9 \text{ psu Sv}}{\frac{0.1 \text{ psu}}{100 \text{ km}} \times 680 \text{ km}^2} \approx 5 \times 10^3 \text{ m}^2 \text{ s}^{-1}$$

Eddy Scales for $K_Y \approx 5 \times 10^3 \text{ m}^2 \text{ s}^{-1}$

mixing length model:

$$K_Y \approx u' l \quad (\text{velocity scale} \times \text{length scale})$$

$$5 \times 10^3 \text{ m}^2 \text{ s}^{-1} \approx 0.1 \text{ m s}^{-1} \times 50 \text{ km}$$



Isohaline volume budgets: issues

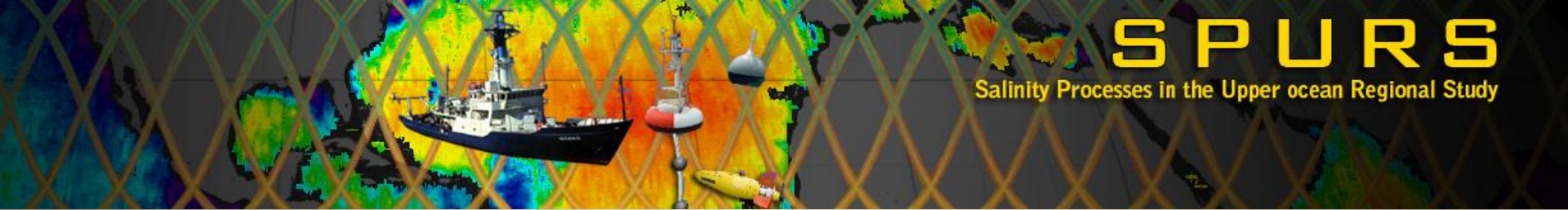
What is the variability in the surface area of $S > 37.0$ on seasonal and interannual times scales? (Aquarius, WOA...)

What is variability of the volume? (Argo, ...)

What is time dependence of K_v ? (Seagliders, mooring...)

What is the drifter salt flux across $SSS=37.0$?

What is effect of seasonal cycle of mixed layer deepening on vertical fluxes? (moorings, Seagliders, ARGO floats...)

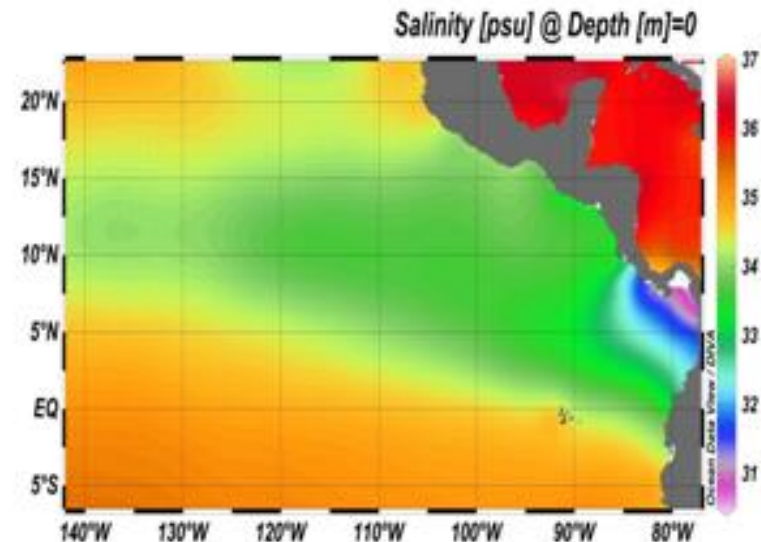
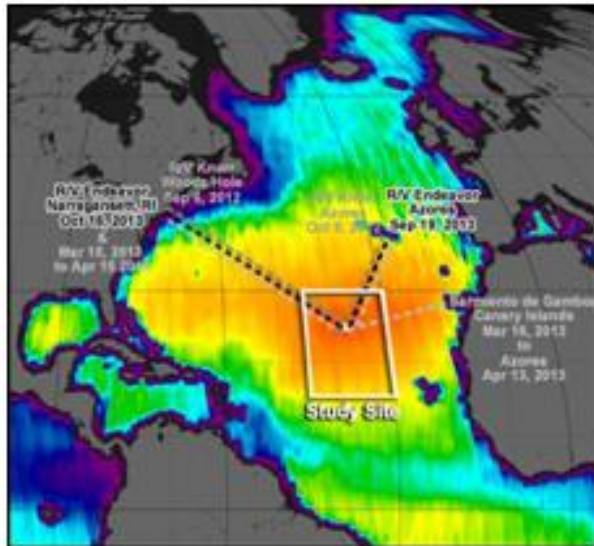


Summary: The Isohaline Control Volume Approach

- The NA Salinity Maximum yields purely oceanic isohaline control volumes, providing a unique opportunity for budget calculations.
- The microstructure measurements can estimate the amount of vertical mixing, allowing for estimates of lateral diffusivities.
- Increased vertical resolution should be possible using other isohaline surfaces.
- Lateral mixing mechanisms may be quantified in the rich set of SPURS mooring, float, drifter and glider data.
- The isohaline control volume is a promising integrating approach to pull together the diverse SPURS observations.
- Many interesting questions arise: Seasonal and inter-annual variability of the volume, long term trends, specific mixing mechanisms....

SPURS 2 Planning Meeting

From Salty to Fresh



SPURS-1 examined the salt balance in the North Atlantic Salinity Maximum, and we now want to explore the physics of a fresh oceanic regime in SPURS-2. Come and help us plan the next experiment at the:

SPURS Spring Meeting for Synthesis and Planning
Pasadena, CA, April 16-18, 2014

<http://spurs.jpl.nasa.gov/SPURS/index.jsp>